Thus with a lens 100 mm. focal length, aperture ratio F. 7, field 50°, the greatest diameter of the image of any point (defect due to i) is 0·2 mm. approx.; that of a point on the axis (defect due to e) will be approx. 0·02 mm.

For these values the effect of terms in T of higher order would be appreciable; but the results justify the practice of correcting a single component—the back one—for astigmatism and spherical aberration, *provided* due attention is paid to the securing of the condition for no distortion.

"On the Discharge of Electricity from Hot Platinum." By HAROLD A. WILSON, D.Sc., B.A., Fellow of Trinity College, Cambridge. Communicated by C. T. R. WILSON, F.R.S.

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(Abstract.)

This paper contains an account of a series of experiments on the discharge of electricity from hot platinum wires. The main object of the investigation was to determine the influence exerted by the nature of the gas in which the wire is immersed. The first part of the paper contains a short account of some of the results obtained by previous investigators. The rest of the paper is divided into the following sections:—

(1) Description of apparatus, &c.
(2) The leak in air, nitrogen and water vapour.
(3) The variation of the negative leak with the temperature.
(4) The leak in hydrogen.
(5) The leak from palladium in hydrogen.
(6) Summary of principal results.
(7) Conclusion.

The wire used was of pure platinum, and was mounted like the filament of an incandescent lamp, in a glass tube. A platinum cylinder surrounded the wire, and the current from the wire to the cylinder, with various differences of potential between them, was measured with a galvanometer. The wire was heated by passing a current through it, and its temperature was determined from its resistance.

It was found that at low pressures using a wire not specially cleaned a large negative leak could be obtained. This leak, however, was not the same on different occasions with the same wire, nor with different wires at the same temperature. The leak on first heating a wire is very large, but falls off with the time. If the wire is then left cold for some hours the leak is again large on first heating and falls off as before. If the wire is kept at a constant temperature and the leak measured for

a long time, irregular variations in the leak occur, especially with a wire which has been much heated.

The wire disintegrates when heated at low pressures and evolves gas. If the pressure is kept constant, by pumping, the apparatus of course soon gets filled with the gas evolved by the wire, which is mostly hydrogen. The leak measured under such circumstances is, therefore, not the leak in air but that in hydrogen, which, as will be shown below, is much larger than that in air, and depends on the amount of hydrogen in the wire. When the wire is first heated hydrogen is gradually driven out of it and so the leak falls off. On standing cold the wire again absorbs some of the hydrogen, and so the leak is larger again when the wire is heated.

Long-continued heating causes the surface of the wire to become covered with a network of deep cracks, and it seems probable that the irregular variations in the leak which sometimes occur are connected with the formation of these cracks.

The sudden opening of a crack exposes a fresh surface of platinum, and may suddenly set free some occluded hydrogen, and so produce a sudden increase in the leak. It appears that the last traces of hydrogen can only be got rid of with the greatest difficulty, and the wires continue to evolve gas when heated in a vacuum for an extraordinarily long time.

In order to measure the leak in pure air, precautions were taken to get rid of the hydrogen. The wire, after being mounted in its tube, was boiled in nitric acid, and then washed with distilled water. It was then heated to a high temperature in air at atmospheric pressure, and then the air was pumped out until the pressure was very low, the wire being kept hot all the time. Air was then let in again, and pumped out, several times. This treatment entirely got rid of all the irregularities in the negative leak, and greatly diminished the evolution of gas by the wire.

Cleaning the wire with nitric acid, and changing the air in this way, was found to diminish the leak to something like one thousandth part of its ordinary value, and very thorough cleaning of the wire with nitric acid diminished the leak to about one part in 250,000.

The presence of traces of phosphorus pentoxide was found to enormously increase the negative leak, and it is known that alkali salts have a similar effect. The results obtained lead to the conclusion that the negative leak is due to the presence of traces of hydrogen, or possibly other substances in the wire. The reasons for believing that the leak is mainly due to hydrogen will be mentioned later.

With a particular wire, treated in the way described, in air, the small remaining negative leak only falls off slowly at a constant temperature, and does not vary in an irregular manner, so that its variation with the pressure and temperature can be measured.

The negative leak in air at constant temperature in general increases with the pressure. This is shown to be due to ionisation of the air produced by the collisions of the negative ions coming from the wire with air molecules. If the P.D. used is small, no ionisation by collisions occurs, and then the negative leak is independent of the pressure at low pressures.

If n_a ions leave the wire, the number n_b of ions reaching the cylinder is shown to be given approximately by the formula

$$\log \frac{n_b}{n_a} = \frac{\mathrm{V}}{\mathrm{E} \log \frac{b}{a}} \left\{ \epsilon^{\frac{-\mathrm{NE}pa}{\mathrm{V}} \log \frac{b}{a}} - \epsilon^{\frac{-\mathrm{NE}pb}{\mathrm{V}} \log \frac{b}{a}} \right\}.$$

In this formula

V = potential difference between wire and cylinder,
b = radius of cylinder,
a = radius of wire,
p = gas pressure,
N = maximum number of negative ions produced by one negative ion in going 1 cm. at unit pressure,
E = potential through which a negative ion must fall to enable it to ionise an air molecule.

Professor Townsend has shown that the number α of negative ions produced by one negative ion in going 1 cm. is given approximately by the formula

$$\alpha = \mathrm{N}p\epsilon^{\frac{-\mathrm{NE}p}{\mathrm{X}}},$$

where X is the electric intensity. This formula of Townsend's is used in deducing the above expression for n_b/n_a.

It is shown that N varies nearly inversely as the absolute temperature of the gas through which the negative ion moves.

The variation of the negative leak with the temperature is investigated theoretically on the assumption that the liberation of negative ions or corpuscles at the surface of the platinum is analogous to the evaporation of a liquid, and the formula

$$x = \mathrm{A} \sqrt{\theta}\, \epsilon^{-\mathrm{Q}/2\theta}$$

is obtained.* In this formula

x = negative leak per sq. cm. of platinum,
θ = absolute temperature,
Q = energy in gramme calories required to produce 1 gramme molecular weight of ions,
A = a constant.

* A formula of this type was first used by the author to calculate the energy necessary for the production of ions from the temperature variation of the leak from hot platinum in 1901. See 'Phil. Trans.,' A, 1901, p. 430.

It is found that this formula accurately represents the variation of the negative leak with the temperature. Q is found to be 130,000, and it is shown that it cannot vary more than one part in one hundred thousand per degree Centigrade. The value of the constant A is shown to be diminished by cleaning the wire with nitric acid. With a wire boiled for a few minutes in nitric acid $A = 7 \times 10^7$, while with a wire very thoroughly cleaned $A = 6 \times 10^6$.

The negative leak in hydrogen was measured and found to be very much greater than in air. At low pressures, using a P.D. too small to produce ionisation by collisions, the current is proportional to the pressure of the hydrogen. The leak from a wire in hydrogen at 0·1 mm. pressure is several thousand times that from a clean wire in air or in a vacuum.

It is shown that the negative leak in hydrogen depends on the amount of hydrogen absorbed by the wire. When the temperature or pressure is suddenly varied, it takes a considerable time for equilibrium to be established between the hydrogen in the wire and that outside, and the leak varies in consequence with the time. The following table gives the negative leaks at 1400° C. at several pressures in hydrogen.

Pressure.	Current per sq. centimetres.
133·0 mms.	$1 \cdot 0 \times 10^{-3}$ ampère.
0·112 "	$1 \cdot 2 \times 10^{-5}$ "
0·0013 "	$2 \cdot 0 \times 10^{-7}$ "
0·0 "	$1 \cdot 2 \times 10^{-10}$ "

The following table gives the values of the constants Q and A found for wires in air and hydrogen at several pressures:—

Pressure.	Q.	A.
(1) Thoroughly cleaned wire in air or vacuum	155,000	$6 \cdot 0 \times 10^6$
(2) Cleaned wire in air or vacuum	131,100	$6 \cdot 9 \times 10^7$
(3) 0·0013 mm. H_2	120,000	10^7
(4) 0·112 " H_2	85,900	$5 \cdot 3 \times 10^4$
(5) 133·0 " H_2	36,000	0·1

If we regard the leak in air, or a vacuum, as due to traces of hydrogen occluded in the wire, then we see from the above table that Q steadily increases as the amount of hydrogen in the wire diminishes. The constant A, however, increases with increasing quantity of occluded hydrogen, when very little hydrogen is present, but when the amount of hydrogen is further increased it attains a maximum, and then diminishes. The fact that the negative leak in air at low pressures always falls off with long continued heating, confirms the view that it is due to occluded hydrogen. Treating the wire with nitric acid

enormously diminishes the negative leak, and also, to a large extent, stops the evolution of gas from the wire when it is heated. The nitric acid, of course, oxidises the hydrogen.

O. W. Richardson* has recently published two papers on the negative leak from hot platinum and other substances. He obtained large negative leaks from platinum, which behaved in the irregular manner which I have described above as occurring when using wires not specially cleaned. The results which I have obtained do not confirm the theoretical conclusions to which he has been led.

The paper also contains the results of measurements of the positive leak in air and hydrogen. The results confirm the view that the positive leak from clean wires is due to ionisation of the gas molecules at the surface of the platinum.

The view put forward in this paper with regard to the negative leak is that it is generally due to the emission of negative ions by hydrogen occluded in the platinum. Other substances, such as phosphorus pentoxide and alkali salts, also give rise to a negative leak when they are present. Air and nitrogen do not appear to produce any negative leak appreciable on a galvanometer.

It is probable that a pure platinum wire heated in a perfect vacuum would not discharge any electricity at all, either positive or negative, to an extent appreciable on a galvanometer.

* 'Proc. Camb. Phil. Soc.,' vol. 11, Part IV; 'Roy. Soc. Proc.,' vol. 71, 1903.